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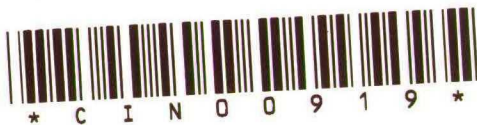
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REPRINT



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Reprinted from W. Driehuis, M.M.G. Fase and  
H. den Hartog (eds), Challenges for Macroeconomic  
Modelling, Contributions to Economic Analysis  
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## THE HISTORY OF DUTCH MACROECONOMIC MODELLING (1936-1986)

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### 1. INTRODUCTION

'A dynamic theory of the business cycle, if fully elaborated in precise terms, so as to do some justice to the enormous complexity of the real world, requires a highly complicated mathematical technique and presents formidable problems from the purely logical point of view'. In this way Haberler concludes Part I of his famous Prosperity and Depression, of which the first edition appeared in 1937. In a footnote he refers to the work of Frisch and Tinbergen as an example of this approach.

This statement by Haberler well expresses the intellectual challenge of constructing a framework which could bridge the gap between the business cycle theory of those days and the reality of economic fluctuations. The approach taken by Frisch and Tinbergen, but also by others (e.g. Kalecki) consisted in applying the mathematics of solving (linear) differential and difference equations to sets of economic relations. By assigning sufficiently realistic values to the constants in such a system one might be able to simulate a dominant wavelike movement of the economy with a periodicity of about 8-11 years: the business cycle.

In this sense two of the many contributions of Frisch and Tinbergen to the development of a mathematical theory of the business cycle are of special interest, because they specially aim at matching theory and fact. Seen against the backdrop of later developments these attempts are rather crude, but in their time they were quite novel. A brief review of them might help recreate the intellectual landscape in which the first full-fledged macroeconometric 1936 model of Tinbergen appeared.

The contribution of Frisch (1933), presented orally at the Leyden meeting

of the Econometric Society in 1933, addresses itself to the issue of the endogenous nature of the business cycle. As he patiently explains, cycles can be generated by nonperiodic impulses depending on the intrinsic characteristics of the economic system. To generate cycles the system should relate the present to the more or less distant past. In the simple case of a linear economy the cyclical nature follows from the value of the parameters of the underlying relations. By selecting for these some more or less realistic values (a marginal capital-output ratio of 10, a depreciation rate of 20 percent e.g.), Frisch is able to let his model generate cycles of 8.6, 3.5 and 2.2 years, next to a monotone damped component.

In the Frisch model the basic imbalance giving rise to cyclical movements is the one between the production of producer or investment goods on the one hand, and that of consumer goods on the other hand. Prices do not play any role. In the model of Tinbergen (1935), however, the price level is playing the leading part. One may summarize his model as a hog cycle or cobweb model for macroeconomic consumption. Using quarterly data for the United States (1920-1933) and for Germany (1925-1933) the supply of consumer goods (volume) and the demand for these (value) are explained as a function of the retail price level, its change and a trend. The two equations are fitted by the method of least-squares with the coefficients divided by the correlation coefficient. One may consider this three equation model (the third equation being the identity linking price, volume and value) as the first published estimated macroeconomic model.

In many respects this first model is very primitive when compared to the model which Tinbergen used for his paper read at the 1936 annual meeting of the Dutch Association of Economics and Statistics. This latter model truly marks the beginning of a long tradition of model building and for that reason alone deserves a detailed discussion, to be taken up in the next section.

The 1936 Tinbergen model gave the building of models for the Netherlands and in the Netherlands a headstart. Many models have been constructed, for the Netherlands as well as for other countries, regions, blocks of nations, the world. It is not the purpose of the present contribution to review them all. A first glance at the survey of Uebe et al. (1986) would show such an endeavour to be self-defeating. The emphasis will instead be

on how Dutch modelling activity responded to the needs of macroeconomic policy, how it incorporated new theoretical insights concerning the working of the economy and how it absorbed technical innovations in estimation and model simulation. To limit further the scope, models that have not lived beyond a doctoral dissertation are not discussed, as are other models that have hardly been put to use. This historical review also concentrates on the Dutch tradition. Many models of the Netherlands have been built as part of multinational modelling projects. One of the first of these is to be found in Von Hohenbalken and Tintner (1962). These will also be left out. Still it is possible that models have been omitted that in the view of some should have been included. Perhaps it happened because the author was not aware of their existence, perhaps it was consciously done to keep the review within reasonable bounds.

The paper is organized as follows. The 1936 Tinbergen model, together with a later variant of it, is discussed in some detail in the next section. One had to wait until 1953 before the Central Planning Bureau (CPB) installed its first model. Since then, it has been the center of modelbuilding in the Netherlands. The string of models developed and used by the CPB in the late fifties and in the sixties is being reviewed in Section 3. The following section is then devoted to the newer generations of models produced at the CPB since then. The virtual monopoly\* of the CPB in modelling came to an end in the mid seventies. Section 5 summarizes some of the models that have been constructed at other institutions. Section 6 will, from a distance, look back at this half century of modelbuilding.

The pioneering role of Dutch modelbuilding in the earlier years stands out clearly. This justifies the telescopic structure of this paper with its focus on the more distant past at the cost of less detail on more recent developments. As far as the latter flow over into ongoing work, they will be anyway covered in other contributions to this conference.

## 2. THE 1936 TINBERGEN MODEL

The title of the English translation [Tinbergen (1959)] of the 1936 paper is 'An Economic Policy for 1936'. It nicely summarizes the slightly long-winded question which serves as the title of the original paper: 'Is a



recovery in the domestic economic situation of this country possible, with or without action on the part of the Government, even without an improvement in our export position? What can be learned about this problem from the experience of other countries?' This was the question the Board of the Association put before Tinbergen, then associated with the Central Bureau of Statistics and part-time professor at the Netherlands School of Economics in Rotterdam. Tinbergen limited himself mainly to the first part of the question. He specially built his model to answer it.

By 1936, economic conditions in the Netherlands had become worse and worse since 1929. World trade on which the country depended so much had dropped by 30 percent. Net national income per capita at constant (market) prices had decreased by 18 percent. Registered unemployment had gone up from 2.8 percent in 1929 to 17.4 percent in 1936 [see CBS (1979)]. Quantitative import restrictions and higher tariffs aimed at keeping foreign competition on the domestic market at bay. Minimum prices for farm produce were introduced to maintain farmers' income at sustenance levels. Nominal wages of those that had a job, however, had gone down less than the cost of living index. Moreover, consumption per capita had not changed much since 1929 but its distribution was more unequal. The surpluses of central government of the late twenties had turned into a series of deficits. The government headed by Colijn tried hard to curtail its expenditure. The trade balance was less negative than in more prosperous years because imports had decreased more than exports. Colijn defended the position that without a sound currency there was no way back to prosperity. He kept the guilder at its (overvalued) gold parity in a world where the major currencies had already left the gold standard for years.

What then could be done to reduce unemployment and to restore prosperity, while respecting some balance of the current account? Would matters improve by themselves if left alone? A public works programme, perhaps, as proposed by the socialist movement in their Labour Plan? More import restrictions? Rationalization? Reduction of profit margins? Or of wages? Or perhaps a devaluation, risking foreign reprisals?

Tinbergen's model tried to supply the means to formulate an answer to these questions. It is worthwhile to have a closer look at it. It is a system of 24 linear equations of which 15 are reaction equations with in

most cases estimated coefficients. Six equations contain lagged endogenous variables on the right-hand side, making it a dynamic model. We will take up various aspects in turn.

### 2.1. Variables

The variables are mostly quantities, prices and values of labour, consumption, exports of goods, imports of finished consumer goods and those of production equipment, imports of raw materials for the production of consumer goods or for that of producer goods. The distinction between consumer goods and producer goods is typical for a segment of business cycle theory of that time. A strategic role is played by non-wage or other income, also called profits by Tinbergen. One misses concepts like stock changes, government consumption, gross national or domestic product, indirect and direct taxes, which are familiar components of most models since the system of national accounts was fully developed. Investment or gross fixed capital formation is implicitly defined. Absent from the model are monetary and financial variables, like the interest rate, money supply and various forms of credit. The exogenous variables are the world price level, the price levels of the various imports, the volume of world trade, the income from investment abroad, i.e. the international environment. The time trend is, of course, also an exogenous variable. Note that exports of goods and their prices are endogenous in the 1936 Tinbergen model.

### 2.2. Data

The observations on the variables are taken from various sources. The paper gives the annual values for 1923 through 1933 for all variables. For 1934 most values are given, for 1935 the information is less complete. All but one equations are estimated for an eleven year sampling period 1923-1933. In the case of equations with lagged variables the relevant 1921 and 1922 values are absent but they can be reconstructed from the graphs of the equations. The prices are scaled so that the average for 1923-1933 equals 100. The values are expressed in units of 17.54 million guilders, being the 1923-1933 average (divided by 100) of the wage bill. The quantities are defined accordingly.

### 2.3. Specification

The model is conceived as a business cycle model. The equations describe variations around a linear trend. This is reflected in the fact that the variables in the equations are expressed as deviations from the 1923-1933 mean while many equations contain a trend term. This term is omitted from the presentation of the equations but can be retrieved from the graphs.

### 2.4. Estimation

Most of the equations have been estimated by least squares, or rather by a variant of least squares also known as diagonal least squares. The least squares regression coefficients are divided by the correlation coefficient to correct for the asymmetry in the treatment of left-hand side and right-hand side variables in ordinary least squares. Since most of the correlation coefficients are close to one this correction is of minor importance.

In a few equations multicollinearity prevented obtaining plausible values for some of the coefficients. These were then assigned a reasonable value. Next to the intercepts, at most three regression coefficients per equation were estimated. Tinbergen, helped by B. Buys, performed the calculations with paper, pencil and slide rule. Redoing these calculations using a computer showed differences in the outcomes, but none of those were consequential [see Dhaene and Barten (1988)]. Inconsistency due to simultaneity is an academic question if the sample covers only eleven observations. Moreover, the  $R^2$  are generally rather high. To silence all doubts on this score the residuals of the Tinbergen equations have been regressed on the explanatory variables using as instrumental variables the exogenous ones of the system. The resulting chi-square values are so small that the hypothesis of no inconsistency cannot be rejected. It appears, however, that the estimates are very sensitive to the data. Using one observation more may make a considerable difference for the point estimates.

### 2.5. Identities

The model contains two additive definitions. One describes total consumption as the sum of consumption by wage earners, identical to the wage bill, and that of other income earners. The other one defines total output



as the sum of consumption and commodity exports. The data do not obey this latter identity. The other seven identities are linearizations of the value-equals-quantity-times-price relations. As an example, take the case of commodity exports.

$$U_A(t) = u_A(t) + 0.88p_A(t) - 88 \quad (2.1)$$

Here  $U_A$ ,  $u_A$  and  $p_A$  are the value, volume and price of commodity exports, respectively.  $t$  represents a year. The value of 88 is the 1923-1933 average of both  $U_A$  and  $u_A$ . As a measure of the precision of the approximation one may use  $R^2$ . It is 0.984.

## 2.6. Reaction equations

We will present some examples and start with the consumption function. The model explains consumption as a function of income but in a differentiated way. A first component is consumption by wage-earners. These are supposed to consume all of their primary income ( $L$ ) without delay. Other income ( $Z$ ) is only partially (68 percent) paid out to its earners and with an average delay of 0.27 years. Of this amount ( $E$ ) 26 percent is consumed now and next year. Tinbergen's function is written as:

$$E'(t) + E'(t+1) = 0.26E(t) - 1.8t + 224.07 \quad (2.2)$$

where  $E'$  is consumption by 'other income' earners. The constant has been added to make it simple to work with the level values of the variables. The  $R^2$  of this equation for the 1923-1932 sample period is 0.94. The marginal propensity to consume out of paid-out other income is only 13 percent. It seems somewhat low considering that farmers, retailers and craftspeople are among these income earners. For comparison, we add here the least-squares reestimation results of this equation:

$$E'(t) + E'(t+1) = 0.229E(t) - 1.793t + 229.9 \quad (2.3)$$

(0.054)            (0.274)    (10.27)

$R^2$ : 0.942    SER: 2.18    DW: 2.07    Sample period: 1923-1932

where the standard errors are given in parentheses below the coefficients,



SER denotes the standard error of regression and DW the Durbin-Watson statistic. Clearly, the differences are minor. Note that relative prices do not influence consumption levels.

## 2.7. Investment equation

The model does not contain an investment variable as such. No doubt data were lacking for this concept. Tinbergen assumed that investment activity is proportional to imports of means of production. The factor of proportionality is three times larger when these means are raw materials rather than finished products, reflecting the assumption that 2/3 of the value of the finished product is value added. The dependent variable of his investment equation is thus  $v'_A + 3y'_A$ , where  $v'_A$  is imports of finished means of production and  $y'_A$  is imports of raw materials (inputs) for the production of investment goods. The explanatory variable is 'other income' ( $Z$ ) and a trend:

$$v'_A + 3y'_A = 0.51Z(t-1) + 2.93t - 48.10 \quad (2.4)$$

with  $R^2 = 0.887$ . Although perhaps profit expectations is the appropriate explanatory variable, no information about that is available and past profits are the best proxy for it. The rate of interest does not appear in this equation. It is a relatively unimportant part of total investment costs in the first place and its role does not show up in empirical investigations. Prices of shares are roughly parallel to profits so there is no room for them in this equation. Tinbergen (1935) found little unambiguous evidence of the acceleration principle, which was so popular with the business cycle analysts of that era. This explains the absence of production changes in (2.4). Explaining investment by profits will turn out to be characteristic for Dutch modelling. In the model, the  $y'_A$  part of investment determines the amount of labour in the producer goods industry (b). Moreover, the degree in which investment goods are locally produced rather than completely imported as measured by  $y'_A - v'_A$ , is made dependent on the difference between the price of imported investment goods and that of locally produced ones ( $q'_A - q$ ).

### 2.8. Labour demand

The part of total labour (a) working in the consumer goods industry (a-b) is considered to be engaged in processing imported raw materials for consumption ( $x'_A$ ) and to a much lesser degree in processing finished consumer goods ( $u'_A$ ). The equation reads:

$$a(t) = b(t) + 0.2u'_A(t) + 1.0x'_A(t) - 0.28t + 23.05 \quad (2.5)$$

The coefficients of  $u'_A$  and of  $x'_A$  have not been estimated. The importance of the effects can be gauged from the respective elasticities: 0.12 for a with respect to  $u'_A$  and 0.41 for a with respect to  $x'_A$ . The  $R^2$  of this equation is 0.905. In the model  $u'_A$  and  $x'_A$  depend on total production (u) while the extent to which consumer goods are home produced rather than fully imported depends on the differential of consumer prices (p) and the price of imported inputs into the production of consumer goods.

### 2.9. Consumer prices

Tinbergen's price equations represent supply behaviour. In his model demand determines the quantities, sometimes independent of prices, like in the case of consumption, while supply sets the prices, mostly independent of the quantities. The basic ingredient is a cost component consisting of import price of raw materials, the wage rate (l) and a productivity trend. The profit margin depends on the corresponding foreign price level and in the case of consumption on the total quantity produced (u). The consumer price equation, for example, takes the following form:

$$p(t) = 0.15 (r'_A + 2l - 6t) + 0.04p'_A + 0.08u(t) + 24.20 \quad (2.6)$$

The coefficients in the cost term have not been estimated. Still, the equation has a very close fit:  $R^2 = 0.980$ . The effect of the price level of imports of finished consumer goods ( $p'_A$ ) is weak and computationally sensitive. When reestimating the equation it turned negative, although not significantly different from zero. In a later version of the model [see Tinbergen (1937)] it was omitted. As is evident from (2.6) long-run price homogeneity is not respected.

## 2.10. Wage rate

In the 1936 Tinbergen model the equation for the wage rate ( $l$ ) is specified as follows:

$$\Delta l(t) = 0.27\Delta p(t-1) + 0.16a(t) - 16.28 \quad (2.7)$$

which shows that the change in the wage rate is made dependent on the change in the cost of living in the preceding year and on the level of employment ( $a$ ). In a sense this specification anticipates a Phillips type of wage determination. Its  $R^2$  equals 0.897, which is not too high, but the standard deviation of the residuals is less than one percent of the sample mean. There is a problem with this equation, however. In the stationary state  $\Delta l$  and  $\Delta p$  are zero and  $a$  equals 101.75 regardless of the exogenous conditions. This implies that all measures of economic policy that do not change the intercept in (2.7) cannot effect the employment level in the long run. The same is true for external conditions like world trade. This is an unfortunate property for a model oriented towards the design of an employment policy. At the time of its presentation this aspect seems to have escaped the attention of its author. However, in a revision [see Tinbergen (1937)] this equation was replaced by:

$$l(t) = 0.36a(t-1) - 0.9t \quad (2.7a)$$

which avoids the problem just mentioned.

## 2.11. Export equation

Commodity exports  $u_A$  are proportional to world trade and depend positively on the world price level lagged a quarter and negatively on the price of exports. The elasticity of exports with respect to its own price is -1.43 evaluated for the sample mean, that with respect to the world price level is 2.38. These values center around -2, the value of the substitution price elasticity of exports implicit in an earlier study [see Tinbergen (1936b)] and incorporated in so many of the later Dutch models.

## 2.12. Other income

The 'other income' or profit variable ( $Z$ ) plays a major role in the model. Its structural equation is a mixture of a definition and of a reaction



function. The variable itself was calculated as the estimated national income of persons plus the non-distributed income of enterprises minus the wage bill. Only the latter appears as such in the model. The other two components are implicitly approximated by the equation. A first part is made up of the value added (the term is then not yet in use) of the production of consumer goods, production equipment and commodity exports from which the wage bill is subtracted and to which income from investments abroad (the colonies overseas) is added. Profits are not only the rewards of production. They can result from speculation or appreciation of stocks, which are considered to be related to the increases in import prices of raw materials and of finished consumer goods. The value of financial investments is taken to reflect in profit levels. As the change in this value can be considered as part of profits the question contains a term in  $\Delta Z(t)$ , introducing a further element of dynamics in this equation. The coefficients of the second part of the equation have not been estimated by regression methods but resulted from an educated guess. The equation displays a considerably high fit. It is of interest to note that  $Z$  peaks in 1928. It drops in 1929 already because exports remain constant (at a high level) while income from abroad continues its decrease since 1926. In the model only lagged  $Z$  appears as explanatory variable. It determines investment and the consumption of non-wage earners. Because it absorbs virtually all other variables in the model the  $Z$  equation plays a pivotal role in the dynamic interactions of the model.

### 2.13. Simultaneous interdependence

Qualitative structural analysis shows that the model consists of a central simultaneous block of 14 equations, preceded by two recursive equations and followed by a string of eight post simultaneous recursive equations. The degree of simultaneity is considerably reduced when the wage rate ( $l$ ) is made independent of employment ( $a$ ).

### 2.14. Solution procedures

The model does not contain policy instruments as variables. Policy changes are introduced as exogenous shifts in the relevant equation. Replacing the other exogenous variables by assumed values and the lagged variables by observed values Tinbergen solved the model in two steps. First, by way of

substitution and elimination all endogenous variables, except the wage rate, are expressed in terms of the wage rate, the lagged wage rate, the lagged increase in consumption prices, the lagged profits ( $Z$ ) and a constant. Next, a small recursive system in the five endogenous variables that also appear in lagged form is set up which is then solved simultaneously and consecutively, resulting in a time path for these variables, one for each policy alternative. These time paths are then used to calculate the values of other endogenous variables. One of the time paths corresponds with no specific policy. It serves as the reference solution. As such it could serve as a pure prediction. Still as Driehuis (1986) remarks Tinbergen does not pay much attention to it. He is more interested in the differential policy effects that can be read off from the differences between the time paths for the various policies and the reference solution. His approach is the one modern model users practice too to evaluate their simulations. However, the Tinbergen model is linear and has constant multipliers. There are then simpler ways to calculate the differential effects.

## 2.15. Multipliers

The linearity of the model has been used to derive the reduced form, the impact, interim and total multipliers by matrix algebra. In Table 1 one finds the multipliers of an incidental autonomous increase in investment in year  $t=0$  by one unit on gross domestic product (GDPQ), on employment ( $a$ ), on consumer prices ( $p$ ), the trade balance (TBV) and on other income for the years  $t=0, \dots, 10$ . The last row represents the sum of all the multipliers over  $t=0, \dots, \infty$ . The first column resembles most the Keynesian investment multiplier concept. (GDPQ is defined here as  $u+2y'_A-u'_A-x'_A$ ). As one sees it is less than one. This low value can be explained as follows. Derived investment increases only next year because it depends on  $Z(t-1)$ . There is a small derived increase in consumption of about 0.36. The gross effect of a 1.36 production increase entails imports of 0.65 resulting in a net effect of 0.71. Observe that this is the total effect of an autonomous increase in investment on GDPQ, i.e. national value added, which combines the direct and the derived effect. In the model the structural share of value added to investment is 0.5. Thus the total effect is 1.4 times the direct effect as far as value added is concerned. As

Table 1a Multipliers of autonomous investment  
(single one unit impulse in  $t=0$ )

Year	GDPQ	a	p	TBV	Z
0	0.710	0.420	0.049	-0.650	0.994
1	0.422	0.226	0.049	-0.396	0.177
2	0.010	0.015	0.035	-0.069	-0.050
3	-0.006	-0.015	0.038	-0.031	0.025
4	-0.043	-0.017	0.030	-0.016	-0.063
5	-0.014	-0.018	0.035	-0.023	0.019
6	-0.042	-0.017	0.028	-0.015	-0.058
7	-0.014	-0.017	0.033	-0.021	0.016
8	-0.039	-0.016	0.027	-0.014	-0.052
9	-0.015	-0.016	0.031	-0.020	0.013
10	-0.036	-0.015	0.025	-0.014	-0.048
$\Sigma_{0,\infty}$	0.050	0.000	1.360	-1.845	0.353

Table 1b Multipliers of autonomous investment  
(permanent increase by one unit from  $t=0$  on)

Year	GDPQ	a	p	TBV	Z
0	0.710	0.420	0.049	-0.650	0.994
1	1.132	0.646	0.108	-1.046	1.171
2	1.142	0.661	0.143	-1.115	1.121
3	1.136	0.646	0.181	-1.146	1.146
4	1.093	0.629	0.211	-1.162	1.083
5	1.079	0.611	0.246	-1.185	1.102
6	1.037	0.594	0.274	-1.200	1.044
7	1.023	0.577	0.307	-1.221	1.060
8	0.984	0.561	0.334	-1.235	1.008
9	0.969	0.545	0.365	-1.255	1.021
10	0.933	0.530	0.390	-1.269	0.973
$\infty$	0.050	0.000	1.360	-1.845	0.353

further appears from Table 1 the trade balance (TBV) is reduced, which is due to the increase in imports. Employment and prices go up. The second year effect is still attractive but already substantially less than the impact effect. In later years the effects become small. Pump-priming does not work here. Note the fluctuating sign of Z, indicating a two-year cycle. Table 1b gives the effects of a permanent unit increase in autonomous investment. The bottom line gives the change in the stationary state. It appears to be small. The zero for employment is due to the nature of wage rate equation (2.7). Table 2 displays the effects of a permanent increase of all foreign prices by one unit (about 2 percent). The impact in year 0 is rather small but that in year 1 is substantial. Note the



perverse J-effect on the trade balance.

Table 2 Multipliers of foreign price increase (devaluation)  
(permanent increase by one from  $t=0$  on)

Year	GDPQ	a	p	TBV	Z
0	-0.021	0.017	0.161	0.272	3.086
1	1.665	0.840	0.334	-0.559	2.611
2	1.286	0.667	0.351	-0.339	2.290
3	1.253	0.624	0.395	-0.342	2.444
4	1.186	0.606	0.413	-0.339	2.244
5	1.217	0.587	0.456	-0.372	2.391
6	1.134	0.568	0.474	-0.375	2.214
7	1.160	0.554	0.514	-0.406	2.344
8	1.085	0.540	0.532	-0.409	2.185
9	1.107	0.523	0.569	-0.438	2.299
10	1.039	0.510	0.587	-0.442	2.157
$\infty$	0.207	0.000	1.426	-0.999	1.607

The increase in foreign prices relative to domestic prices causes in this model a shift from imports of finished goods to imports of raw materials and hence only a rather limited decrease in imports which is more than compensated by the increase of imports because of domestic expansion. The volume of exports is rather insensitive. It depends on the difference between the world price level and the export price level, which is never allowed to be larger because the export price level depends positively on the world price level. The effects on GDP and employment are initially strong but taper off. Domestic prices adjust to the international ones. As the last line of Table 2 shows there is even an overadjustment, due to the absence of price homogeneity in the model. This last line also shows that employment returns to its old level, as is implied by equation (2.7). Still, real wages as well as other income are higher.

## 2.16. Dynamic characteristics

The interim multipliers show a gradual decrease. The endogenous fluctuations of the model are definitely damped. Calculating the eigenvalues that characterize these fluctuations they turn out to be all real and less than one in absolute value. The non-zero ones are 0.9723, -0.9421, 0.1148 and 0.1075, respectively. The two first ones are close to one in absolute value. This corresponds with the rather slow convergence of the multi-



pliers. The negative one corresponds with the two-year cycle mostly due to the way consumption function (2.2) is formulated and to the determination of other income ( $Z$ ). For a business cycle model absence of conjugate pairs of complex eigenvalues is somewhat disappointing, because these would have caused more interesting cyclical patterns. The two-year cycle is more an artifact of the model than a reflection of the real state of affairs.

## 2.17. Implementation

Tinbergen investigated seven different policy scenarios. Two of these involved a devaluation of the guilder by 30 percent. He finds it the most attractive alternative. He addresses the meeting of the Dutch Economics Association on October 24, 1936, but his paper is already available in September. On September 27 the minister-president Colijn abandons the gold parity of the guilder, reluctantly following the example of the People's Front government of France and that of Switzerland. The guilder devalues effectively by 17-20 percent.

## 2.18. Evaluation

One cannot help but be deeply impressed by the enormous step forward which the Tinbergen 1936 model was. Virtually unprecedented Tinbergen produced a model of no less than 24 equations, justified on the basis of economic reasoning and empirical experience, fitting the scarcely available data well. It made it possible to answer questions of great practical importance with an exceptional degree of coherence. Artus et al. (1986) consider the model's linear structure, its weak theoretical basis and the non-empirical nature of some of the coefficients as its basic shortcomings, as seen from the present point of view. One might not entirely agree with this judgement. Surely from the 1936 point of view the linear structure was a strong point of the model. The theory behind it was much more articulate than contemporaneous contributions including that of Keynes (1936), while reliance on non-estimated coefficients is even today a common feature. Perhaps, with a collective experience of fifty years, one would do certain things differently now. Perhaps, one realizes somewhat better the limitations of the approach, because of that experience. Still, this does not detract from the unique qualities of the original contribution. Going over the old text, trying to derive again the published results, one finds

out over and over again that every detail is justified, that little or nothing is left to luck, but almost all is consciously selected.

## 2.19. Sequel

Tinbergen (1937) is somewhat more than a version in English of his 1936 paper. It not only contains a more elaborate discussion of the dynamics involved. Also the model is changed in a number of ways. As already mentioned, the wage equation (2.7) was replaced by (2.7a), making the model more suitable. Consumption function (2.2) with the slightly awkward left-hand side is changed into:

$$E' = 0.065 (E(t) + E(t-1)) \quad (2.2a)$$

reducing the somewhat spurious two-year cycle which was in part caused by the original equation. The savings equation was changed in a similar way. Commodity exports and export prices were made exogenous. The model thus counts 22 equations. Minor adjustments were made to the equation of the consumption price and that of other income. The total or long-run multiplier effects on employment are now nonzero. The impact multiplier of autonomous investment on GDP is 0.73, close to the value of Table 1a, but the long-run multiplier is now 0.88, still below one but substantially higher than the 0.05 of Table 1b. All eigenvalues characterizing endogenous dynamics are real. The dominant one is -0.44, i.e. negative, but rather small. The other nonzero ones are 0.17, 0.03 and -0.02, respectively. There is a dominating two-year cycle which soon dies out. Tinbergen (1938) developed still another model for a report by the Dutch Labour Council on employment policy. Although it differs from its predecessors the differences are rather subsidiary. One of Tinbergen's co-workers, Polak (1939), used the 1936 model to derive for the Netherlands a reduced form equation for domestic activity as a function of world trade and the exchange rate. Such type of equations were estimated for seven other countries. It is a first attempt in setting-up an interlinked multinational model.

In the meantime Tinbergen had temporarily moved from the Central Bureau of Statistics to Geneva as an expert with the Economic Intelligence Service of the League of Nations. There he refined the methodology [Tinbergen

(1939a)] and assisted by Polak constructed a 50-equations model for the United States [Tinbergen (1939b); see also De Wolff (1983)]. This project was sharply criticized by Keynes (1939) to which Tinbergen (1940) replied. As Keynes feared, Tinbergen's reaction to this critique was not so much to give up model building but 'to drown his sorrows in arithmetic'. More specifically a 39-equation model for the United Kingdom was constructed. It was published much later [Tinbergen (1951)]. Around the same time Radice (1939) published a pocket-size forecasting model for the United Kingdom. It is not our purpose to go further into these developments. Anyway, World War II effectively stopped activities in this area. When later on they were resumed on both sides of the Atlantic [see Klein (1950) and Klein and Goldberger (1955)] one could start with the knowledge that model building was feasible as Tinbergen had so amply demonstrated by constructing relatively large econometric models for three countries in slightly more than three years.

### 3. MODELLING AT THE CENTRAAL PLANBUREAU: THE EARLY YEARS

In 1945 the Central Planning Bureau (CPB) was established with Tinbergen as its director. Its 1947 charter states as its main duty the formulation of a 'balanced system of forecasts and directives for the Netherlands economy'. A macroeconometric model of the type Tinbergen had been pioneering would have been the perfect tool for this task. However, World War II had left the Dutch economy in ruins. Its recovery was severely hampered by scarcity of foreign exchange. An extensive system of rationing of imports, consumption and investment was put in force to make the most out of what was available. Coffee, for example, was rationed through 1951. Housing much longer. A more or less refined model implicitly assuming free interaction among the major economic variables was of little use in this situation. As recovery proceeded a gradual relaxation of the physical controls became possible. At the same time the need for a model, able to make coherent predictions for the uncontrolled variables, made itself felt.

The problems of the early 1950s centered around the balance of payments, employment, the wage level (centrally fixed) and the level of investment. Unemployment was increasing in spite of an active emigration policy. The model that was eventually adopted was directed at policy formulation for



these issues. It was published in an Appendix to the Central Economic Plan 1955 and is therefore known as the '1955 Model'. It had been constructed earlier and was already in use in 1953. It was adjusted marginally in later years. Here, we will base ourselves on CPB (1956) which gives the structural form of the 1955 model without commentary. It served as a basis for the prediction and policy advice of the CPB for most of the 1950s.

The 1955 model consists of 27 equations describing the major macroeconomic aggregates as defined by the system of national accounts. Its equations are in the first differences of the variables. It is hardly dynamic. Preceding year levels enter in linearizations. Only the investment equation, based on the flexible accelerator mechanism, is truly dynamic. At the time of the construction of the model post-war time series of sufficient length for estimation were not available. Its coefficients, therefore, were based on input-output information, on regressions on pre-war data, including cross-sectional ones and on information on the tax and social security systems. In some cases simply a plausible value was used. Taxes and unemployment allowances are endogenous. A number of other income transfers are exogenous. In fact, most aspects of government behaviour are exogenous. Monetary variables are absent. To appraise the model better we will look at some of the structural equations in detail.

### 3.1. 1955 consumption function

It is in the same spirit as the one of the 1936 Tinbergen model. Combining the equations for consumption out of wage- and out of other income one has

$$\Delta C(t) = 0.85\Delta L_B(t) + 0.40\Delta Z_B(t) \quad (3.1)$$

where  $C$  is private consumption expenditure,  $L_B$  disposable wage income and  $Z_B$  disposable or other income. As compared to the 1936 Tinbergen model wage earners have a lower propensity to consume while other income earners have a higher one.

### 3.2. 1955 investment equation

Investment is explained by the flexible accelerator principle in first differences:

$$\Delta i(t) = 0.10 [2.5(\Delta v(t) - \Delta n(t)) - \Delta i(t-1)] + \Delta i_v(t) - \Delta d(t) \quad (3.2)$$

with  $i$  being net investment,  $i_v$  replacement investment,  $d$  depreciation,  $v$  gross output of enterprises and  $n$  changes in stocks, all measured in constant prices. The coefficient 0.10 is the speed of adjustment and 2.5 is the marginal capital-output ratio adjusted for the optimal degree of utilization of capacity. This equation has been revised in later versions of the model. Among other things, dwellings have been excluded from the capital stock. Correspondingly, rents have been subtracted from  $v$  and the coefficient of 2.5 was lowered to 1.8. The model treats  $n$ ,  $i_v$  and  $d$  as exogenous. Note that the choice of the accelerator explanation is very much at variance with the Tinbergen approach to investment, which uses (expected) profits as the explanatory variable. In practice, equation (3.2) was not fully utilized for prediction. Predictions were in part based on an investment survey with the largest firms.

### 3.3. 1955 Labour demand

This equation is based on Verdoorn's law [see Verdoorn (1949, 1951)], which states that the rate of growth of labour productivity is 0.6 of the rate of growth of production. Consequently, the rate of growth of labour demand is 0.4 times that of production. No allowance is made for substitution of labour by capital or vice versa.

### 3.4. 1955 imports equation

Imports are related to the categories of final demand using import contents obtained from an input-output table. In this way one differentiates between the low import intensive outputs like consumption, export of services, and government expenditures on the one hand and the high import intensive other outputs: investments and exports. Also here there are no price effects.

### 3.5. 1955 export equation

Exports are made dependent on the difference between the export price and the competing world market price level with an elasticity of -2, based on pre-war studies by Tinbergen. Since the model explains the export price

level as the average of a cost component and the competing international price level the price difference will be small and the price dependent part relatively unimportant. The part of exports that does not depend on prices is fixed exogenously.

### 3.6. Price equations

The role of prices in the 1955 model is modestly limited to converting quantities into values. Their equations are based on cost components: wages, import prices and autonomous shifts in indirect taxes. As in the 1936 model price homogeneity is not respected.

The 1955 multipliers of GNP with respect to autonomous investment and government expenditure are about 0.5 and 0.9, respectively, reflecting the high import content of domestic expenditure.

With respect to the 1936 Tinbergen model the 1955 model takes a step forward in its compatibility with the system of national accounts and in the explicit presence of variables related to government action. It scores lower because of the virtual absence of dynamics, the very limited price-quantity interaction and the somewhat weaker empirical basis. While in the 1936 Tinbergen model only foreign price and world trade are exogenous, the 1955 model treats many other, domestic, variables which are really endogenous as exogenous like depreciation and stock changes. Also the wage rate is exogenous. This was justified by the wage policy at that time which fixed a uniform wage increase. The wage rate was a kind of policy instrument.

Forecasting at the CPB is an almost continuous activity. The 1955 model was used for that purpose only twice, perhaps three times, a year. Several ad hoc adjustments then had to be made to let these forecasts be plausible. In the meantime the forecasts were updated informally.

The model played a much more important role in the design of economic policy. It could easily be used to draft a table indicating the consequences of particular measures of economic policy like those of an indirect tax increase for employment, investment, consumer prices, and current account of the balance of payments. The lack of dynamics helped here,



because only current effects were relevant. Such a compact table - see for example the Centraal Economisch Plan 1957 - enabled decision makers to choose their favourite policy menu. Locally, these tables acquired a certain fame under the name 'spoorboekje', railway guide.

The model was also important internally at the CPB. Because of its relative transparency people could easily grasp the underlying reasoning. The staff became model minded. It also homogenized their vision of the working of the economy. Until proven wrong the model was taken to be right. With a more complicated model such a change of attitude would have been more difficult and slower.

The fact that an official institution was using a macroeconometric model was internationally unique. At the time models were being built elsewhere, for example by Klein, as academic exploits. Official institutions remained sceptical about the possibilities of models for their work. The CPB was clearly doing pathbreaking work.

The 1955 model is basically a short-run model. For the formulation of long-range projections a different type of model is needed. It was designed by Verdoorn (1956). It is a model of 17 equations, many of them nonlinear in the variables and coefficients. The latter have been obtained in various ways. There is some correspondence with the 1955 short-run model. Demand for labour and capital are simple functions of GNP only. The price elasticity of exports is -2. The model is a growth model for an open economy. Long-run equilibrium of the balance of payments basically determines the rate of growth of output. Given this, equilibrium on the labour market implies the rate of growth of income. Via accounting identities exports are determined. Exports and income determine savings available for investment, which then have to correspond with the capital needed. The overdetermination of the model can be used to turn assumptions into endogenous variables. The most optimistic forecast for a twenty year period ending in 1970 implied an annual growth rate of per capita GNP of 1.7 percent. In reality it was 3.6 percent, twice as large. This underestimation is, however, mostly due to the underestimation of the exogenous component of exports (world trade). Rather than the assumed 4.8 percent its actual growth rate was more than double, viz., 10.3 percent.



Figure 1: Calculation sheet Investment Price Equation (C. Kwinkeleberg)



The need for a better short-run model was clear. Its construction was conceived as a large scale project ('An Econometric Analysis of the Netherlands Economy') with wide support. The initiative was taken by Tinbergen and Idenburg, the director-general of the Central Bureau of Statistics (CBS). In addition to the CPB and the CBS, the Netherlands Economic Institute in Rotterdam and the Mathematical Center in Amsterdam participated. Some support was obtained from the Netherlands Science Foundation. Koyck of the Netherlands School of Economics and Verdoorn were the principal investigators. As it turned out, the center of gravity of the project was the CPB, where Verdoorn was in charge of it.

A first stage of the project was the construction of an adequate data base. For the post-war years most of the data needed were normally published by the CBS. However, the first usable year was 1948. When working with changes and lags few post-war observations were available. A joint effort of CBS and CPB resulted in a data base for the period 1922-1939. For the first version of the new model about 22 annual observations were now available of which 16 dated from before World War II. These latter data were of interest because they showed more fluctuations than the post-war ones which were mainly trends. To avoid arriving at a model which would be better geared to the remote past than the more recent and relevant one the post-war observations counted twice as heavy as those of the 1923-1938 period. The data set for the pre-war period was not published as such. Only recently the CBS released more or less detailed national accounts for the years 1921-1939 - see Van Bochove and Huitker (1987).

The combination of the two data bases entailed another problem. The levels of the variables were perhaps not comparable across the two periods. Assuming that relative changes, however, were comparable the equations of the new model were formulated in terms of percentage changes of the variables. An additional advantage was that the coefficients are elasticities. The accounting identities have to be 'linearized' as expressions in percentage changes. The price-quantity-value identities are almost naturally linear in those transformations.

The initial versions of the model - see e.g. Verdoorn and Van Eyk (1958) - were estimated by ordinary least-squares. Calculations were performed by hand using desk calculators. Figure 1 presents by way of example the cal-



culatation sheet for the regression of the price of investment goods. One was, of course, very much aware of the development of simultaneous equation estimation techniques by the Cowles Commission in the late forties and early fifties. In fact, Theil (1954) developed the method of two-stage least-squares (2SLS) at the CPB as part of the modelling project. This method assumes that the list of exogenous and lagged endogenous variables is known and smaller in number than the number of observations. For the initial stage of model building where various alternatives for structural equations are 'screened' the first condition is not satisfied. The second condition is even more precarious for models of more than a few equations and with a variety of lag patterns. Anyway, given the small sample size any worry about inconsistent estimation seems to be excessively scrupulous.

Still, the 1961 version of the new model was estimated by a version of 2SLS, in particular the one developed by Kloek and Mennes (1960). It is the model used for the drafting of the Central Economic Plan 1961 and published as its Annex 1. It is a system of 36 equations linear in the percentage changes of the current variables with one notable exception: the rate of unemployment, used as a proxy for capacity utilization, appears in some equations in a nonlinear transformation. As compared to the 1955 model, the 1961 model is fully dynamic. It is also more endogenous. The wage rate is still exogenous even though the central wage policy had been relaxed some years before. Monetary variables appear: time and demand deposits at the end of the year, as an indicator of liquidity, and the discount rate of the Central Bank. The quantities respond to price variations. The model is much more geared to the Dutch economy of the late fifties and early sixties than the 1955 model which still so much reflected the extreme scarcities of the years right after World War II. It is also less demand-driven (or Keynesian) than its predecessor. Investment is explained mainly by profits rather than by output, returning in this way to the Tinbergen approach.

To highlight some of the model's features we will discuss a few of its structural equations.

### 3.7. 1961 Consumption function

Using  $\nabla$  to indicate percentage changes, the equation for private consumption reads

$$\begin{aligned} \nabla C(t) = & 0.64 \nabla L_B(t-\frac{1}{2}) + 0.17 \nabla Z_B(t-\frac{2}{3}) + 0.46 \Delta \nabla P_C(t) \\ & - 0.16 \Delta \nabla C(t-1) + 0.05 \nabla C^r(t-1) - 0.63 \end{aligned} \quad (3.3)$$

with  $P_C$  being the price index of private consumption and  $\nabla C^r(t-1)$  the percentage change in demand and time deposits at the end of the preceding year.

One may note the relatively complicated dynamics: lags and changes of percentage changes. The presence of the term in  $C(t-1)$  is justified by the type of reasoning which nowadays is associated with the Error Correction Mechanism (ECM), originally proposed by Sargan (1964) and more recently reintroduced by Davidson et al. (1978). The short-run income elasticities of 0.64 and 0.17 are rather low, their long-run counterparts even smaller in contrast with the hypothesis of long-run proportionality of consumption and (permanent) income postulated by Friedman (1957). The deposits variable ( $C^r$ ) is a proxy for available liquid assets.

### 3.8. 1961 Investment equation

The dependent variable of the investment equation is the percentage change in nonresidential private investment in fixed assets. Its explanation is almost perfectly that of an ECM. The long-run equilibrium value depends on other income after taxes, the price of investment goods, liquidity ( $C^r$ ) and the degree of utilization of capacity. The current first difference in this variable explains the short-run fluctuations around this level. The dependence on other income or profits is a typical supply-side feature of the model. (Under)utilization of capacity is proxied by the rate of unemployment which enters this equation in a nonlinear way. For low unemployment values the effect on investment is very strong, reflecting the need for investment when the economy is operating at a high level of capacity utilization. This indeed was the case for the Dutch economy in most of the fifties and sixties.

### 3.9. 1961 Labour demand

The equation of labour demand reflects on the one hand Verdoorn's Law, with an elasticity of 0.39 (rather than 0.4!), and on the other hand a profit effect. Another supply-side feature. The differential between import and domestic production prices also plays a role, albeit minor.

### 3.10. 1961 Imports equation

This equation links imports to the categories of final demand in roughly the same way as the 1955 version does, except that it is dynamically more refined. Also differential price effects appear.

### 3.11. 1961 Exports equation

The long-run price elasticity of exports is now close to -3. Furthermore Dutch exports are growing 1.5 times faster than competing exports. A non-linear capacity effect represents the preference of producers for the domestic market. One can also say that it captures the 'Zijlstra effect': the increase of interest in exports when domestic demand stalls.

### 3.12. 1961 Price equations

These are basically refinements of the 1955 ones, with cost per unit of output as the major explanation. The export price depends in part also on the competing price level. The consumer price equation also contains an ECM. None of the prices react explicitly to variations in demand.

As already remarked the 1961 model is in many respects superior to the 1955 model. Specifically its dynamics are much more refined. The use of ECM's predates their popularity in British econometrics by 15-20 years. Still, the basic economic reasoning is rather similar to that of the 1955 model, except for the explanation of investment.

The 1961 model was soon followed by updates like the Model 62.10 - see Verdoorn and Post (1964) - and the Model 63D. One of the new features was the introduction of an equation for the wage rate, reflecting, with considerable delay, the fact that central wage policy, or incomes policy in general, was virtually abandoned. The wage rate was made dependent on a Koyck lag pattern in prices, productivity and unemployment. The role of



unemployment in this equation was twofold. First, it represents the idea launched by Phillips (1958). Secondly, it reflects the policy to make the model more sensitive to capacity utilization in general. One finds non-linear capacity effects in other structural equations (those for investment, exports, imports, labour demand and export price) as well. The effect of capacity (under)utilization as measured by the rate of unemployment ( $w$ ) was specified as

$$10 \log_{10} (w+2) - 0.2 w$$

with the coefficients selected on the basis of some experimentation. The importance of the role of this variable in the model can be explained by the conditions of overfull employment under which the Dutch economy was operating. At the same time the newer models were stripped of the ECM's of the 1961 model. A first monetary equation was introduced, namely the one for deposits ( $C^F$ ), needed to make predictions more than one year ahead. Deposits also appear in the investment equation where they play a major role.

Verdoorn and Post (1964) pay quite some attention to the solution of the model with a nonlinear capacity utilization variable, which, given the general preoccupation with linear models and their solution techniques, posed a problem. Computers had still to become somewhat faster in order to handle large scale iterative procedures.

Model 63D was left basically unchanged until 1969 when it was reestimated - see Verdoorn et al. (1970, 1971). The extension of the sample period through 1966 made it possible to include additional variables in the various reaction equations. Although these additional variables and the revised point estimates of the coefficients make a difference for the multipliers and the predictions the line of reasoning of the 69-C model is not drastically different from that of its predecessor. Of interest is the introduction of a (negative) effect of investment on employment. It is a first move away from the implicit assumption of mutual independence of labour and capital in production.

During the sixties the need for medium-term analysis and forecasting made itself felt. As Smithies (1957) pointed out, the distinction between on



the one hand business cycle models like the Tinbergen ones which explain short-run fluctuations around a given trend and on the other hand growth models of the Harrod-Domar type which explain the long-run but are silent about the short-run is unsatisfactory. There is a need for integration of both approaches. One can also say that typical short-run models concentrate on the adjustment of demand to existing capacity, and that long-run models explain the development of production capacity, taking appropriate effective demand for granted.

Medium-term models, then, should aim at the mutual adjustment of supply and demand. This is the central theme of the CS model of Van den Beld (1967, 1968). There available capacity follows from a linear production function. Production is determined by the various categories of expenditures. In the structural form the relative overcapacity acts negatively on investment, positively on exports (Zijlstra effect) and negatively on some of the prices and on the creation of liquidities by the banking sector. The consequence is an increase in demand and a reduction in supply, eliminating after a few years the overcapacity. Many of the 24 reaction equations of the CS model are simplified versions of the ones of the Verdoorn class of models. Employment, for example, follows Verdoorn's law with an elasticity of 0.462 and is not related to investment activity. The investment equation of the CS model, however, differs drastically from that of the annual models. Here, next to overcapacity, production and to some extent relative liquidity are the determinants, while profits do not play a role. Supply conditions are represented by overcapacity. In general, the CS model allows little room for price effects. From a computational point of view it is of interest to note that the model contains six broken linear equations, that it is otherwise contemporaneously linear but consecutively nonlinear. These complications could be handled without problems.

The CS model shares with the short-term model the role of capacity utilization as an explanatory variable in structural equations. While in the latter tendencies to restore capacity to a normal level were very weak, they constitute the essence of the CS model. This model, however, was very much an experimental one. Still, it was innovative in several respects: it explicitly aimed at a full time path prediction several years ahead; it was nonlinear; it incorporated explicitly a production function and it treated the interrelations between the real and the monetary sector endo-

genously. It clearly meant another approach to modelling than that with which the CPB had become identified. It has served as a source of inspiration for the newer generations of models at the CPB.

#### 4. MODELLING AT THE CENTRAAL PLANBUREAU, THE LATER YEARS

The appetite comes with the eating. Once year-to-year prediction and policy analysis is under control one wants to monitor the economy with a greater frequency. At the end of the 1960's a quarterly model was developed - see Driehuis (1972). The Central Bureau of Statistics did not until recently (1986) publish a full-fledged system of quarterly national accounts. The missing time series had to be constructed by the CPB itself using various methods, one being the interpolation method of Boot et al. (1967). The series used (1951.1-1965.4) were either without season by the nature of their derivation or were seasonally adjusted. The reaction equations were specified in terms of logarithms of the variables. This is not really a break with the tradition of the Verdoorn class of models with variables expressed in percentage changes. These are virtually proportional to changes in logarithms. Koyck lag patterns and finite lag structures were used to represent the various types of inertia in adjustment and expectations formation.

The model consists of 68 equations of which 21 are estimated reaction equations. In many respects these reaction equations are similar to their counterparts in the annual model. Still there are some important differences. For example, several specifications are explicitly based on a neo-classical optimization scheme. Employment and investment e.g. are both influenced by the user cost of capital in relation to the wage rate, introducing at last some degree of substitution between labour and capital. They also depend on production on the one hand and on profits after taxes on the other hand.

Also relative liquidity and the utilization rate of labour are assigned a role. This eclectic approach is somewhat balanced by the symmetric treatment of demand for labour and that for capital. In virtually all reaction equations capacity utilization plays a role. It is a step backwards from the CS model that only labour is used in the definition of capacity. It

also is inconsistent with the use of a Cobb-Douglas production function with full substitutability. Still its presence in so many equations supplies a unifying element to the model and pays in this way a tribute to the CS model. It also shares with the latter the presence of the liquidity rate as an endogenous variable in several structural equations. It is of interest to note that the long-run price elasticity of commodity exports is -2.045, again in line with the tradition.

The innovative aspect of the Driehuis model is, of course, its quarterly nature. In other aspects it is obviously the offspring of both the Verdoorn and the Van den Beld type of models. Still, its specifications are justified in a theoretically more appealing way. Its analytical content is more substantial.

The Driehuis quarterly model was used for short-run predictions for most of the seventies, until succeeded by KOMPAS. This latter model also integrated components of the VINTAF approach, which we will, therefore, discuss first.

The annual models usually formulated a relatively simple relation between employment on the one hand and production by enterprises on the other hand. Demand for labour was in these models basically independent of capital. Through most of the sixties there was a strong empirical correlation between output and employment. In the late sixties and early seventies one witnessed a further growth in output, but stagnating employment. As the labour force was still increasing this led to increasing unemployment. The CPB predictions consistently missed this development. They overestimated employment.

At the CPB Den Hartog and Tjan (1974) approached this problem by formulating a vintage production model, the core of the later VINTAF models. In this model production capacity is determined by installed equipment, with a constant capital-output ratio. Each unit of equipment requires a certain amount of labour, depending on the vintage of the equipment. The labour requirement per unit of equipment decreases by about 5 percent from one vintage to the next. Capacity increases because of new investment, it decreases because old equipment is scrapped. Scrapping occurs for two reasons. The old equipment becomes either technically obsolete or econom-



ically not profitable, because the labour to operate it is too expensive. The scrapping rule makes labour demand sensitive to real wages. Installation of equipment, investment, is undertaken to replace scrapped capacity or in response to gross profits after taxes. Stagnating employment in manufacturing with growing output and capacity can then be seen to follow from a replacement of old vintages with high labour requirements by new ones with low labour requirements.

The idea of a vintage production function goes back some time in the literature - see e.g. Johansen (1959) and Solow (1960) - but was not given an operational implementation. It is the great merit of Den Hartog and Tjan to surmount the rather formidable empirical complications of the approach, although this sometimes meant cutting the Gordian knot. Their work justly drew international attention.

The vintage production block was imbedded in a full model. The equations in this model are partly linear in the levels of the variables, partly linear in the logarithms of the variables, partly in terms of percentage changes. VINTAF II, the second version of the model, counts 112 equations - see Den Hartog (1980). Apart from the production block VINTAF II is not essentially different from its predecessors. The long-run substitution elasticity of export in VINTAF II is  $-1.7!$ .

A new phenomenon occurred. The presentation of VINTAF II and its use for policy analysis caused considerable discussion. A special double issue of *De Economist* (volume 124 (1976) issue 1/2) was published with both a translation of Den Hartog and Tjan (1974) and critical comments and a discussion of related topics. A lively debate developed in *Economisch-Statistische Berichten* in the period August 1977 - August 1978, triggered off by a provocative contribution by Driehuis and Van der Zwan - see Driehuis and Van der Zwan (1978). The debate led to further research on the specification and estimation of vintage models as summarized by Den Hartog (1984).

The discussion around VINTAF II was novel. Never before had a CPB model been so closely analyzed in public. The critique directed itself primarily at the model assumptions and not so much, as had sometimes happened before, at the model outcomes. The CPB models were no longer sacrosanct.

The VINTAF model, surely not perfect, was clearly a step forward over the earlier annual models. Its data base was completely post-war. It was not confined by linearity of its relations. Its major innovation, though, was to explain potential demand for labour in conjunction with investment activity.

In the early eighties VINTAF was succeeded by FREIA. This model - see Hasselman et al. (1983) - integrated a model of the real sector largely based on VINTAF with a monetary model developed at the CPB. Its empirical basis is formed by annual time series for the period 1954-1975/1978. Its real part consists of 257 equations. The monetary submodel counts 75 equations.

The real submodel has a more refined explanation of investment in equipment where in addition to replacement needs and profitability expected sales play a role. Actual employment is described as a weighted mean of the demand and supply of labour with the weights depending on the tension on the labour market. In this way 'disequilibrium modelling' has found a foothold in the CPB modelling tradition. The growth in relative size of the public sector with the ensuing need to try to keep it under control led to a large set of equations for general government and social security.

The addition of a monetary submodel is the important new element of FREIA. It reflected the increased interest in the functioning of the money and financial markets and their interdependence with the real sectors of the economy. For the private and the banking sector an optimal portfolio explanation is used. Such an approach was employed earlier outside the CPB by Knoester (1974, 1980). FREIA takes adjustment costs of changing the portfolio into account. Also a rationing mechanism is introduced in case the desired amounts of assets are not available.

The financial surpluses (deficits) of the non-banking sector result from the real part of FREIA. The interest rate and some assets holdings are fed back from the monetary model to the model of the real sector. Here also 'disequilibrium modelling' has been practiced in cases where interest rates were not supposed to clear markets and strict rationing was not applied. The exchange rate is treated as an exogenous variable. However,

the discrepancy between export prices and competing export prices is used as a proxy for expected exchange rate modifications.

It is perhaps not entirely fair to its authors, Van den Berg et al. (1983), to state that the KOMPAS model is a quarterly version of FREIA. Anyway, the construction of the two models has been coordinated. Like FREIA, KOMPAS has a vintage production block. It has also a similar monetary submodel. KOMPAS too has a large number of equations describing the government and social security sector. The need to specify at the same time the quarterly time structure of the interactions makes it more than a simple copy applied to quarterly data. The fact that the computer listing of the model contains 851 equations clearly reflects this.

The enormous degree of detail for many variables contrasts with a consumption function which is hardly different from the old Tinbergen formulation, apart from a minute interest rate effect. Its specification is not only primitive, also no distinction between durables and nondurables has been made.

It is of interest to note that Koyck lag patterns have not been used to specify delayed effects. In the case of a Koyck lag pattern the use of the Koyck transformation leads to the presence of the lagged dependent variable on the right-hand side of the equation. This causes problems if this variable is not well-determined. The errors are propagated into the future when simulating several periods ahead. Some 24 different lag patterns were used instead for the specification of the KOMPAS equations.

In general, KOMPAS relies less on estimation to determine coefficients than earlier models. The long-run price elasticity of exports, for example, is simply set at -2.

To maintain two models of similar inspiration is a waste of means. It is also confusing. It was only natural to merge FREIA and KOMPAS into a single model: FK 85, presented as 'a quarterly macro economic model for the short and medium term' - see Van den Berg et al. (1987). It is a quarterly model. Its monetary block is taken from KOMPAS. The real submodel is a refined version of the earlier one. Disembodied technological progress is made endogenous allowing for a slower rate of obsolescence in times of



slack and low wage increases. It introduces an element of substitutability after installment. The exogenous reduction in labour requirements per unit of equipment from vintage to vintage, which was originally 5 percent in VINTAF, was further reduced from 3.8 percent in FREIA and KOMPAS to 1.9 percent. Private consumption obtains a more refined specification. Next to current disposable income wealth effects and the rate of interest are allowed to play a role. Other adjustments are made in the real submodel to take into account recent experience with the earlier specifications.

Given the open nature of the Dutch economy the ability to analyse the international environment is of the greatest importance. The BUMO model of the CPB - see Okker and Suyker (1985) and Suyker (1986) describes the world by way of five interlinked submodels: one each for West-Germany, the United States, the Rest of the OECD, the OPEC countries and the Rest of the World.

The special model for West-Germany reflects the fact that that country is the main trading partner of the Netherlands and that the Dutch guilder is tightly linked to the Deutschmark. Economic conditions in the United States affect the Dutch economy more indirectly, but still rather strongly. The growing importance of international monetary and financial relations expresses itself in the presence of monetary submodels and linkages in BUMO.

Recently, the monetary submodel was revised too. The exchange rate as well as the monetary policy of the central bank were made endogenous - see Hasselman et al. (1986).

Finally, one may mention the development of sectoral models. Draper et al. (1987) present VINSEC, a six sector model. It applies the VINTAF approach to sectors. In this way it meets the criticism that the macroeconomic models were too integrated - see e.g. Driehuis et al. (1983a). The BETA model distinguishes fourteen sectors. We will not go into a detailed discussion of these models, in part to limit ourselves to macroeconomic models, in part because they fall outside the reviewed period which ends with 1986.

Looking back at 35 years of modelling at the CPB the first impression is

that of continuity with gradual change. The 1955 and 1961 models borrowed from the 1936 Tinbergen model. The 1961 consumption, investment and export equations are very much like those of Tinbergen. The VINTAF investment equation comes close to that of the 1961 model. Change occurred in response to recent experience or to the need for information. The introduction of labour market pressure in the 63D model reflected the experience of an overfull employment economy with strongly reduced multipliers. This idea was further elaborated in the CS model with a more general definition of tension, involving both labour and capital. The Driehuis quarterly model clearly builds on this tradition with an increasing attention to the analytical justification of the specified equations. Both the CS and the Driehuis models were meeting a need for information: the first about medium-term development, the other concerning very short-run prediction and analysis. The stagnation and decline of employment in the manufacturing industry and the inability to explain it with the available models led to VINTAF, which apart from its use of a vintage production function is similar to its forerunners. The earlier models already contained some endogenous monetary variables. The increasing interest in monetary feedbacks in the seventies naturally led to the development of a full-fledged monetary model linked to a traditional real sector, yielding FREIA and KOMPAS. These models have at the same time extensive sets of equations for social security and general government, meeting a need for detailed information about the variables in question. The merger of FREIA and KOMPAS does not constitute a break with tradition.

At first sight it seems that modelling at the CPB was very much inward looking. Deviations from the tradition were based on own experience and not on developments in the literature or on the experience of other model-builders. Of course, initially there were few competitors to learn from, but partial econometric studies were readily available. Since the mid-sixties modelling has been widespread internationally, but one finds few references to other modelling projects in the CPB publications and progress reports. One has the impression that, on the contrary, model design and usage at the CPB have had a considerable impact on similar work outside the Netherlands, although it is not a simple matter to trace such effects.

The relative insulation of the intellectual environment of CPB modelling

has had the advantage that there was no obvious pressure to jump on the bandwagons of Scandinavian dualism, monetarism, rational expectations, supply side economics, disequilibrium modelling and so on as these came and went. In fact, the CPB models are not easy to classify according to the fashionable nomenclature of modern macroeconomics. The consumption function is usually purely Keynesian, but the investment equation is most of the time characteristic of a supply side approach. In fact, most of the more recent models nicely balance supply and demand explanations.

Our review has not been critical. Criticism from the present point of view is rather easy but irrelevant. More important is the question to what extent the models reflected the state of the art at the time they were constructed. The first models simply were the state of the art. Later on, however, discrepancies could show up. My personal feeling is that the treatment of employment is the truly weak element in the models. The early CPB models explained employment in a very simple and crude way, independently of investment activity. Then all of sudden VINTAF supplied a rather elaborate framework, rigidly tying employment to investment vintages. A more flexible approach taking into account the heterogeneity of the labour force and of the supply of jobs as to age, sex, schooling and location might be indicated. What about the effect of social security and the wage structure on supply and demand? In view of the seriousness of the unemployment problem one would have expected a much more refined analysis than the models offered.

Until some ten years ago the CPB dominated modelbuilding in the Netherlands. Its experience, type of staff, data base and contacts with the centers of decision making gave it a natural comparative advantage over, say, university teams. In one domain the CPB has not exploited that advantage, namely that of monetary model construction. The first models of the monetary and financial sector - e.g. Knoester (1974) - were academic exercises. The monetary models of the CPB, and of the central bank, have, to a certain extent, taken their cue from these efforts.

The virtual monopoly of the CPB in modelbuilding in the Netherlands in the early years effectively gave the CPB model the status of unassailable truth, of the only possible description of reality. Its predictions and simulations were taken too much as certainty and not enough as possibil-



ities with a limited degree of probability. Ignoring the tentative and random nature of models leads to problems when the realizations fall short of the predictions. Fortunately, in more recent years the CPB has competitors presenting alternatives which may if they differ from the CPB analysis create some reasonable doubt or if they agree corroborate it. Modelling activities outside the CPB are the subject of the next section.

## 5. MODELLING AT OTHER INSTITUTIONS

Until the mid-seventies no other Dutch institution or research group undertook the construction of a macroeconometric model of the Netherlands. In other countries, and specifically the United States, model building was mainly an activity of academic research teams - see Nerlove (1966). In part, the absence of university based models can be explained by lack of published data. The data constructed by the CPB/CBS team for the pre-war period and the quarterly data underlying the Driehuis quarterly model were not published. This in a way reinforced the monopoly position of the CPB. Still, there is some evidence that the material would have been made available on request. Anyway it was not until 1976 before a team at the Econometrics Institute of the University of Groningen developed its GRECON model as an alternative to the current CPB model, viz., the 69C model. By that time the post-war time series published by the CBS were long enough for reliable estimation without the pre-war data. The GRECON model has been used for the first time to produce forecasts for 1977. These were published in a March issue of *Economisch-Statistische Berichten*. This exercise was repeated annually, with a reestimated and slightly changed version of the model - see Voorhoeve (1986).

The GRECON project aimed at a relatively concise model. The 1977 model counts 18 equations of which 9 are reaction functions. The 1986 version has only 10 reaction functions supported by 23 definitional equations. The models are linear in annual percentage changes. The linearity made it possible to apply the method of two-stage least-squares in its unadulterated form.

The specification of the equations is somewhat ad hoc. In the 1978 model,

for example, private gross investment (excluding houses) is made dependent on output and on the unemployment rate, without any reference to production functions, relative prices etcetera. The 1986 version of the investment equation also contains output but the unemployment percentage is replaced by gross profit per unit of production, returning to the long-established Tinbergen-Verdoorn tradition in this respect. Private employment depends positively on domestic production and negatively on the wage rate. In the 1977 through 1982 version the coefficient of domestic production is close to the Verdoorn 0.4 value. It increases for later versions to reach the value of 0.64 in the 1986 version. In general, the equations of the early GRECON models look very much like simplified versions of the 69C model of the CPB. GRECON distinguishes itself from that model not so much in the specification of the equations as in the careful econometric estimation and complete documentation.

In the last part of the seventies Driehuis of the University of Amsterdam started the SECMON project. It aimed at filling the need for a sectoral analysis of the Dutch economy. SECMON-A, constructed under commission by the WRR, the Wetenschappelijke Raad voor het Regeringsbeleid (Scientific Council for Government Policy), is a static model covering four sectors: agriculture, manufacturing, construction and services. It also contains a small monetary sector. The SEO, Stichting voor Economisch Onderzoek (Foundation for Economic Research) in Amsterdam adopted the project in 1980. SECMON-B extended its predecessor by being dynamic and covering ten rather than four sectors, but it had no monetary component. It was succeeded by SECMON-C where also wages and prices were modelled. SECMON-D is a further revision. The model is used for research and analysis under contract with various official agencies, non-profit organisations and private firms.

SECMON-D consists of 700 equations. It is an annual model. The category of firms consists of 18 sectors, of which 9 are in manufacturing and 6 are various types of services.

Driehuis et al. (1983) supply in some detail information about SECMON-C which serves as the basis for our discussion. Basically, SECMON is an input-output type model, generating gross output per sector as the sum of the intermediate deliveries to other sectors and of final demand. An input-output framework is also used to link sector prices to those of

primary inputs. Among the categories of final demand total private consumption is explained in roughly the same way as the 1955 CPB model, i.e. as a simple function of disposable wage and disposable other income. It is next allocated over commodity groups as a function of total consumption and a relative price term. Group X (others) is determined as the difference between total consumption and that of the other groups. Private investment is directly determined by sector, either exogenously or as a function of disposable other income, in line with the Tinbergen-Verdoorn tradition. Scandinavian dualism enters the model when the exports for the exposed sectors are made dependent on the price differential between domestic prices and the world price level. Of course, this dualism is also present in the price formation per sector, where the prices of the exposed sectors follow international prices.

SECMON-C uses for the capital intensive industries a linearized clay-clay vintage production model - see Driehuis et al. (1979). It differs from the CPB model in the sense that scrapping does not occur when the oldest vintage in use is not anymore profitable but when the cost of operating the old equipment exceeds the total costs of installing and using the newest vintage. The labour requirements of the vintage in use determine the employment in the capital intensive industries. Since scrapping depends on wage costs employment is sensitive to wages. Employment in the labour intensive sectors depends mainly on value added per sector.

SECMON-C distinguishes itself from CPB models by its sectoral dimension. The economic mechanism underlying the determination of the endogenous variables is however not basically different from that which is incorporated in the CPB models.

After more than a decade of preliminary detailed studies the Econometrics Research and Special Studies Department of De Nederlandsche Bank (DNB), the Dutch central bank, developed an integrated monetary/real model, named MORKMON, for quarterly data - see Fase (1985). It is a natural desire of a policy maker like the central bank to have a macroeconometric model of its own. Close cooperation between model builder and model user is of crucial importance to arrive at a model that meets, even anticipates, the needs of the policy maker. It also contributes to the confidence the latter has in the model, while at the same time making him aware of its limitations.



MORKMON was preceded by two versions of MOKMON, the monetary block - see Fase (1981). The development of the submodel for the real sector had to wait until the quarterly series needed were constructed. The data used for estimating MORKMON are mostly time series starting with the first quarter of 1970 and ending with the fourth quarter of 1979.

Before entering on a discussion of MORKMON the question may be asked why both DNB and CPB were so late in developing interlinked real/monetary models, late not only in comparison to which was done abroad, but also in comparison to the 1967 CS model of Van den Beld as a forerunner of such a model and to the relatively detailed monetary model of Knoester (1974) and its integration with a model of the real sector - see Knoester and Buitelaar (1975)? As far as DNB is concerned, a possible explanation is that its econometrics unit needed time, after being set up in 1971, to build up staff and experience. The CPB has been engaged in monetary analysis since its beginning. It is not clear why it did not try much earlier than FREIA to integrate that analysis with the model for the real sector.

We return again to the DNB model MORKMON. Its monetary submodel consists of over 50 equations. The unifying principle is an optimal portfolio model for the private sector. Such a model explains the composition of the portfolio by the total amount to be invested and all relevant interest rates. The interest rates are in their turn explained by reaction equations. The monetary block also contains a description of the foreign exchange market. The guilder/dollar exchange rate depends on the volume of interventions by the central bank, changes in interest rates in the Netherlands, Germany and the U.S.A., the difference in the U.S. and German inflation rates and the balance of payments surplus, combining the three alternative explanations of exchange rates in one equation. The major determinant however, is the Deutsch mark/dollar exchange rate, which is exogenous in the model. Consequently, the endogenous component of the guilder exchange rate is minor.

The real part of MORKMON comprises 90 equations. 17 of these are reaction functions. Their specification follows in certain respects the CPB tradition. Private consumption depends on disposable labour income and disposable other income separately, gross investment is determined by disposable other income (or profits), prices are explained as a function of costs and

a constant mark-up. Still, there are differences. Private consumption and gross investment also depend on the long-term rate of interest. The long-run price elasticity of exports is -1.2, rather lower than the value used by the CPB. Employment is not based on a vintage production model, although it is made dependent on the stock of capital goods. The latter are decreased by scrapping without identifying the vintage. Since scrapping increases with labour costs, the wage rate affects the capital stock and thus employment negatively. A further feature is the distinction made between output and sales of the private sector. Actual output is determined as a function of expected sales and the desired level of stocks. In this way output is made to depend negatively on stocks.

The two submodels are linked by interest rates and liquidity positions coming from the monetary block and by the private sector's savings surplus, the government deficit and the balance on current account coming from the real block.

MORKMON is in many respects similar to the comparable CPB models, although its monetary block was developed at the same time and quite independently of that of the CPB models. Such similarity does not mean that MORKMON is redundant. An institution like the central bank should be able to express its views in the form of a model, which is, or can be, optimally geared to its needs.

The Macroeconomic Policy Unit of the Erasmus University Rotterdam started its RASMUS project in 1982. It aims at studying the international ramifications of macroeconomic policy by constructing sets of interrelated national models. It started with a model for the U.S.A. and one for a block of 6 members of the European Community. As the project developed a model for the Dutch economy was introduced separately. The interesting aspect of this project is its complementarity to the other Dutch models which usually treat the international environment in a rather global way and offer few opportunities to study the consequences of international policy coordination.

Recently, the Center for Cyclical and Structural Research (OCSO) of the University of Groningen produced the first version of the OCSO annual model of the Dutch economy - see Kuipers et al. (1987). In spirit, it is

rather close to the VINTAF line of models. However, its vintage model is of the putty-clay variety allowing for substitution between labour and capital for the newest vintage. A detailed discussion of this model would carry us from the past into the present and thus outside the time interval of this survey.

Other models of the Dutch economy have been constructed in the time period of this survey. No doubt a number of doctoral dissertations contain such models. Some models have been published as articles or books - e.g. Knoester (1980). We will not discuss them here. The attention has been centered on models that are part of a continuing operation, that are kept alive and are being used. As the models that were discussed show, the CPB tradition appears to have had a strong demonstration effect. Even though other models try to be different from those of the CPB, to offer an alternative, they still have very much in common with them.

## 6. CONCLUDING REMARKS

The modelling activities reviewed here have not been undertaken for their own sake, out of intellectual curiosity. They were set up to help provide answers to the economic policy problems of their time. Up to a point such policy concerns are reflected in the models. For example, the finely detailed description of the government and social security sector corresponds to the increasing granularity of economic policy.

New insights into the working of the economy have been gradually incorporated. Most of these were internally generated in response to shortcomings of previous models. The upheaval in macroeconomics in the seventies has left few traces in the models.

Modelling activity has increased over time. Several conditions have been favourable for this development. First of all, there has been the development of the system of national accounts after World War II. These accounts supply in a coherent way the lion's share of the data needed for model-building. Incidentally, the fact that the CPB and the DNB had to construct independently their quarterly series indicates that the Central Bureau of Statistics had not been playing the role which, given its fine tradition,



one would have expected.

Secondly, econometric techniques have been developed specifically to estimate dynamic simultaneous systems. The work of the Cowles Commission, directed by Tjalling Koopmans, at the University of Chicago and of Henri Theil, first at the CPB and later at the Netherlands School of Economics deserves to be mentioned in this connection. Although most of the techniques apply ideally to linear models, they can be easily adapted to estimate nonlinear models as well.

Thirdly, calculating has become easier. From the slide rule, via the manually operated and electric desk calculator, the first generation electronic ARMAC in Amsterdam, various other generations of computers to the super computers a long way has been travelled. With the increased memory size and speed of computers there are now virtually no limits on the size of models and nonlinearities can be handled with relative ease.

Fourthly, the number of people able to specify and estimate the structural relations, to simulate the full models and interpret the results has increased. Initially, it was a matter of on-the-job-training. After econometrics became a special field in Dutch universities the supply of potentially competent modellers built up gradually.

Fifthly, initially models and model outcomes were treated with great scepticism by professional economists in and outside government. As the number of people able to understand the possibilities and limitations of models increased criticism based on ignorance was replaced by a more constructive attitude. This did not mean that the models were simply swallowed hook, line and sinker, but that the criticism was directed at specific properties of the models, which could then be amended.

Sixthly, models became theoretically more coherent. The individual structural equations are increasingly specified on the basis of some theory involving several of them. In other words, the specifications tend to be more analytical and less ad hoc. This increases the claim to plausibility of the model, perhaps at the cost of some empirical fit.

The increasing internal coherence of models is no luxury. As models become

larger and larger in size they become less and less easy to control, i.e. they can produce predictions which are hard to understand in an intuitive way. One has to base a model on a relatively few principles, elaborated perhaps in many directions, but rigorously applied in each case. In this way one may avoid the model becoming a big black box. To remain in control over models continuously increasing in size and complexity constitutes in my opinion the intellectual challenge for the current generation of model-builders.

That generation will no doubt continue to build on the work of its predecessors. Working in a Dutch environment one will almost naturally be absorbed in the strong Dutch modelling tradition, which started with the 1936 model of Tinbergen. Looking back, that model seems to be a true act of creation. Out of virtually nothing there appeared a medium-sized macro-econometric dynamic policy model for an open economy. It is difficult to fully appreciate the methodological innovation it represented. The fact that macroeconomic modelling is now commonplace the world over is perhaps its best testimonial.

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